US LHC Accelerator Research Program

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LARP Collaboration Meeting 13

November 4-6, 2009

Materials – Conductor R&D and Procurement

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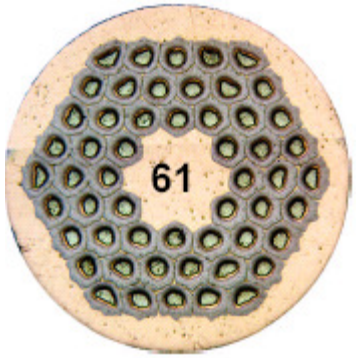
Outline

- Conductor Procurement
  - Specifications
  - Planned purchase
  - Present Inventory
- Strand R&D
- Conclusions

Nb_3Sn HQ-Strand Specification LARP-MAG-M-8002 Rev-B (54/61)

Process	Ternary RRP Nb_3Sn
Strand Diameter, mm	0.8 – 1.0 ± .003
Jc(12 T) at 4.2 K, A/mm^2	≥ 2650
Jc(15 T) at 4.2 K, A/mm^2	>1400
D_s, µm (subelement diameter)	< 100
J_s, A/mm^2	>3000
Cu-fraction, %	53 ± 3
RRR (after full reaction)	≥ 60
Twist Pitch, mm	14 ± 2
Twist Direction	right-hand screw
Minimum Piece length, m	350
High temperature HT duration, h	≥ 48



Increased Copper spacing

Nb_3Sn HQ-Strand Specification LARP-MAG-M-8002 Rev-C

RRP 108/127 with increased Copper

Process	Ternary RRP Nb_3Sn
Strand Diameter, mm	0.7 - 0.8 ± .003
Jc(12 T) at 4.2 K, A/mm^2	≥ 2650
Jc(15 T) at 4.2 K, A/mm^2	≥ 1400
D_s, µm (sub-element diameter)	< 60
J_S, A/mm^2	> 3000
Cu-fraction, %	53 ± 2
RRR (after full reaction)	≥ 60
Twist Pitch, mm	14 ± 2
Twist Direction	right-hand screw
Minimum Piece length, m	350
High temperature HT duration, h	≥ 48

Conductor Procurement

- In FY09
  - Took delivery of 85 kg of 54/61 at 0.8 mm
  - A second 75 kg order placed in Aug'08
    - Strand design 54/61
    - Delivered in Aug '09
  - Ordered 88 Kg of wire Mar-09
    - Initial spec for 54/61 ⇨ Changed to 108/127
    - Delivery in Jan-31-10
  - 67 kg of 108/127 wire ordered Sep-09
    - Delivery Aug-10
  - Pending order 67 kg of 108/127
- In FY10
  - Plan to order 300 kg of wire
- Since FY06 LARP has purchased ~ 1000 Kg of RRP wire

LARP Procurements for HQ

Order Date	Ship Date	Adjusted Ship Date	Quantity, kg	Actual Completed, kg	PO	Billet No.	Cables	
8/30/07	2/28/08	at LBNL	180	37.1, 30.2, 36.6, 38.9, 39.2	6826007	10400 104251 10428 10429 10433	982R TQ 991R-HQ 1000R-HQ	*Rev-F RRP-108/127*
4/15/08	12/1/08	at LBNL	85	29.1, 35.0, 21.6	6846777	10957, 10958, 10973	992R-HQ	*HQ-Conductor 54/61*
9/8/08	7/31/09	at LBNL	75	13.2, 28.7, 33.5	582020	11558, 11559		*HQ-Conductor 54/61*
3/3/09	1/31/10		88		584829			*HQ-Conductor 108/127*
9/3/09	8/31/10		67		588061			*HQ-Conductor 108/128*
11/31/09	11/31/10		67		Pending			*HQ-Conductor 108/129*

Conductor Inventory Summary

- 78 kg of 0.7 mm wire for 2-3 UL's of LQ
- 60 kg of 54/61- 0.7 mm wire from five billets available for practice coils and cable
- RRP 54/61 (increased spacing)
  - 105 kg at 0.8 mm
- RRP 108/127 (increased spacing)
  - 28 kg at 0.8 mm (some in short lengths)

Strand Production

	HQ-54/61 kg	108/127 kg	MAGNET	Strand Req. kg	LQ 54/61 kg	108/127 kg	HQ 54/61 kg
Oct-07					386	0	
Nov-07			LQ01-C03-PC	28	359	0	
Dec-07					359	0	
Jan-08			LQ01-C04	26	333	0	
Feb-08		180	LQ01-C06/C07	51	282	180	
Mar-08					282	180	
Apr-08					282	180	
May-08			LQ01-C08/C09	51	231	180	
Jun-08			TQS03	35	231	145	
Jul-08					231	145	
Aug-08					231	145	
Sep-08					231	145	
Oct-08			LQ-C10/C11	51	180	145	
Nov-08					180	145	
Dec-08	85				180	145	85
Jan-09					180	145	85
Feb-09	13		HQ-987R	23	180	117	75
Feb-09			HQ-C03	23		94	
Mar-09			LQ-C12/C13	51	129	94	75
Mar-09			HQ-PC-C01/C02 *	32	129	94	43
Apr-09					129	94	43
May-09			LQ-C14/C15	51	78	94	43
Jun-09					78	94	43
Jul-09					78	94	43
Aug-09	62		HQ-C04/C05/C06/C07	66	78	28	105
Sep-09					78	28	105
Oct-09					78	28	105

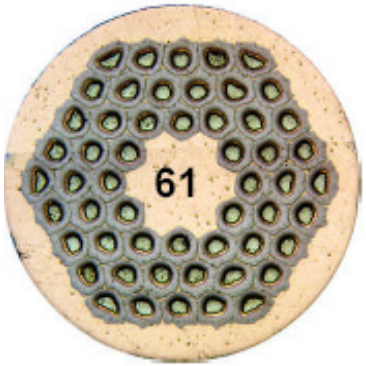
Strand Production

	HQ-54/61 kg	108/127 kg	MAGNET	Strand Req. kg	LQ 54/61 kg	108/127 kg	HQ 54/61 kg
Nov-09			LQ-C16/C17	51	27	28	105
Dec-09					27	28	105
Jan-10		88			27	116	105
Feb-10					27	116	105
Mar-10			HQ-C08/09	36	27	80	105
Apr-10					27	80	105
May-10					27	80	105
Jun-10					27	80	105
Jul-10					27	80	105
Aug-10		68			27	148	105
Sep-10					27	148	105
Oct-10					27	148	105
Nov-10		68			27	216	105
Dec-10					27	216	105
Jan-11							
Feb-11							
Mar-11							
Apr-11							
May-11							
Jun-11							
Jul-11							
Aug-11							
Sep-11							
Oct-11							
Nov-11							

Strand R&D

- Strain Cycling Experiment
- Determine whether strain cycling at RT can degrade I_c
- Use 0.7 mm LQ strand
- Measurements done at NIST
  - Najib Cheggour

Room-Temperature Strain Cycling Effect

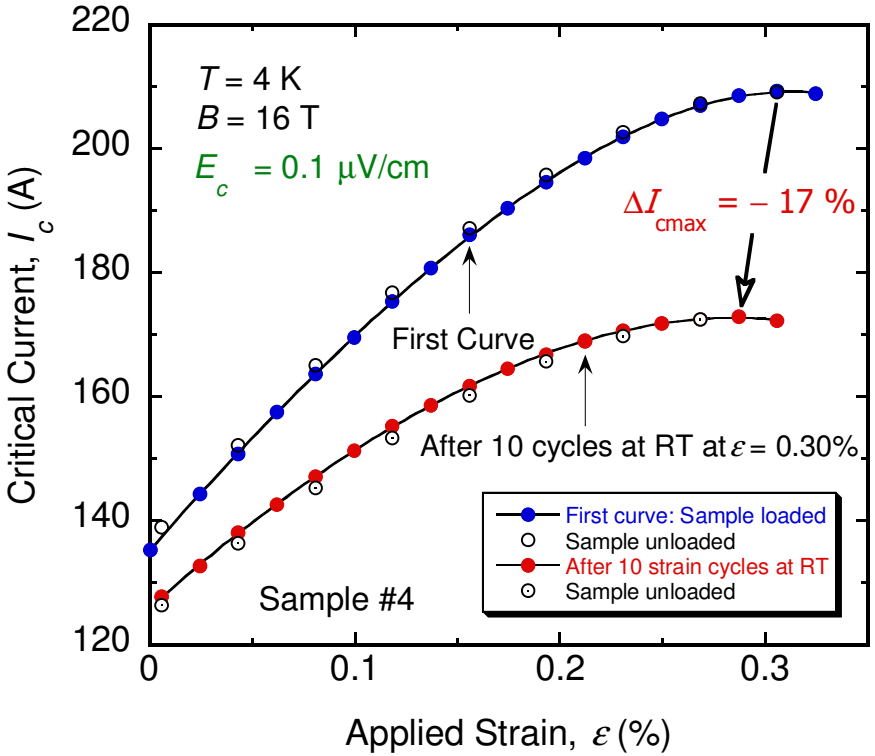


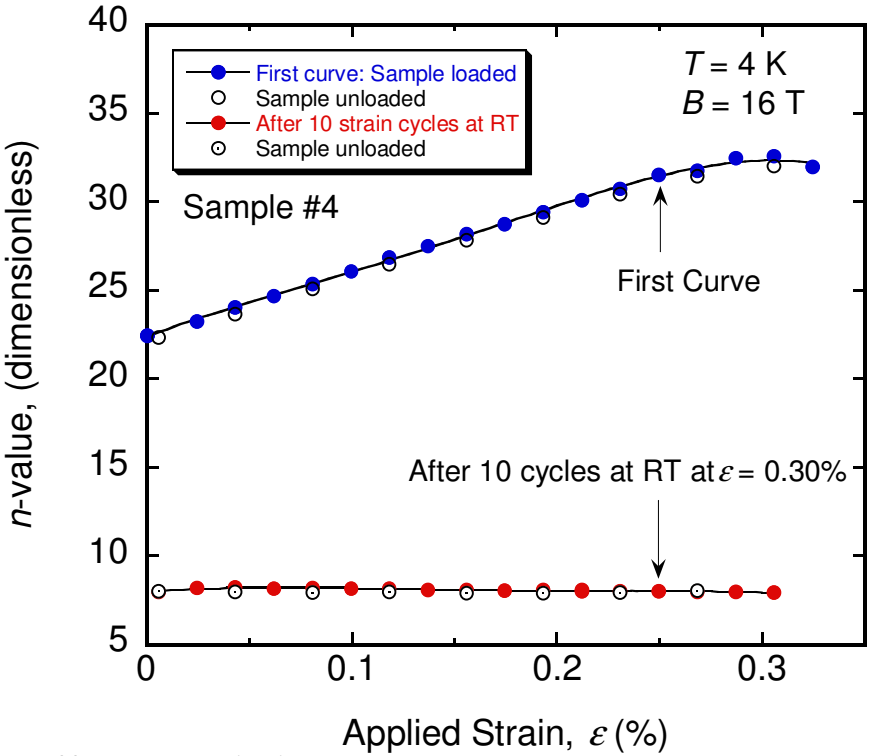
RRP 8781-2 (Ta)
54/61 — ϕ0.7 mm
Non-Cu: 53.9 %
HT: 640 ˚C/48 hours

$\varepsilon_{irr,0}$ **~ 0.04 %**

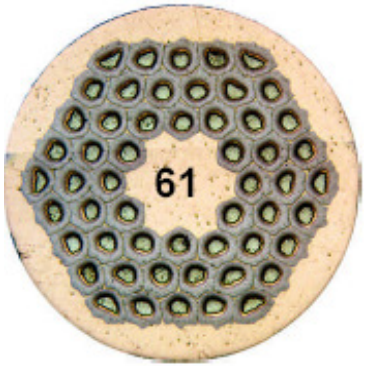
Strain cycling at RT (as small as 10 cycles), at $\varepsilon_{RT} \approx \varepsilon_{max,\,4K}$ (close to $\varepsilon_{irr,\,4K}$), damages I_c and *n*-value

Due to a smaller pre-compression at RT, RRP wire is more sensitive to strain damage at RT than at 4 K





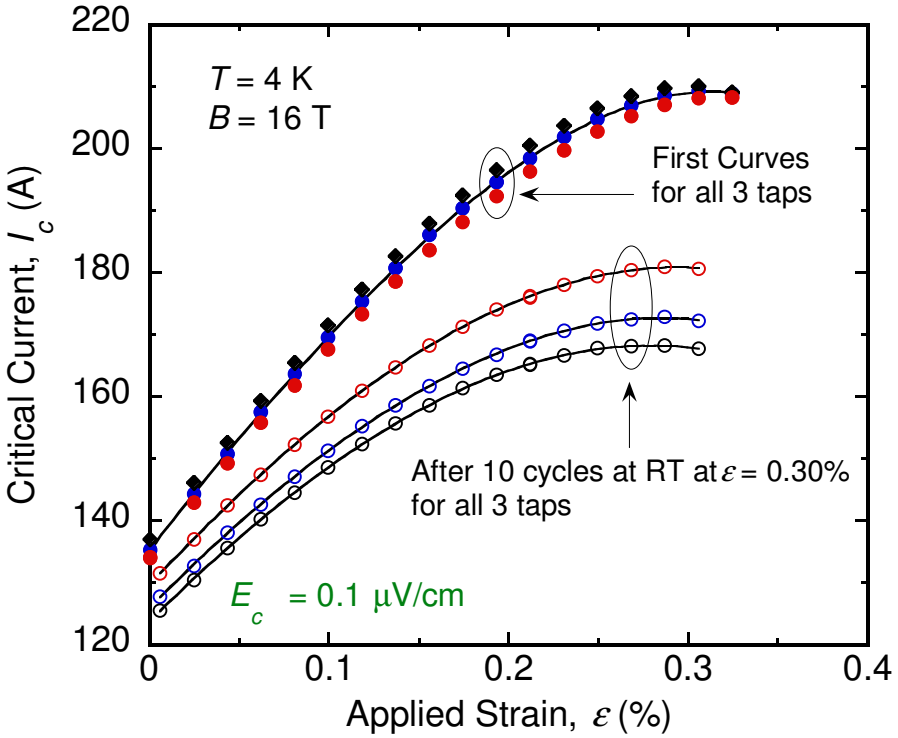
Room-Temperature Strain Cycling Effect

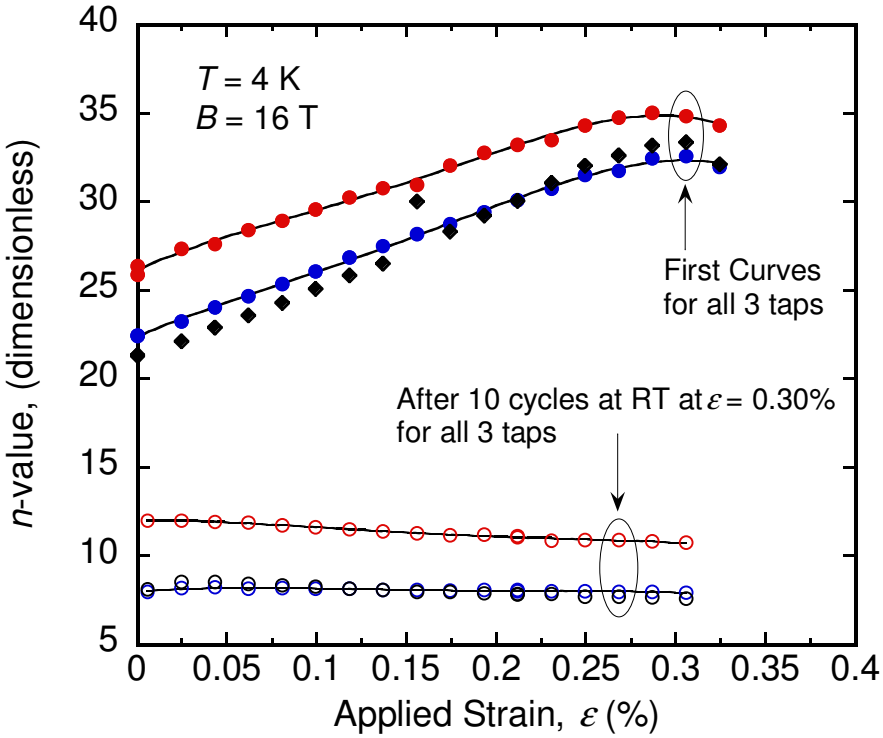


RRP 8781-2 (Ta)
54/61 — ϕ0.7 mm
Non-Cu: 53.9 %
HT: 640 ˚C/48 hours

$\varepsilon_{irr,0}$ **~ 0.04 %**

Damage from RT strain cycling was seen on multiple samples





- There are new results from a study of Ti-doped RRP wires that suggest that Ti-doped wires are more strain tolerant than Ta-doped wire
  - Wire for study used CDP developed billets
    - 54/61 (9415) and 108/127(9416)
  - These will be presented by Najib at the LTSW at Monterey next week. ☛ stay tuned.

Summary

- Present Procurement Plan
  - All wire will be of the RRP 108/127 type 0.7-0.8 mm
  - The planned purchases will satisfy the needs of the HQ program.
  - Long term plan has not been developed.
  - Lead time for strand is now 12-13 months
    - Note: OST has very significant ITER production work